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ANDALUSITE, SILLIMANITE (FIBROLITE), CYANITE AND CORUNDUM FROM QUARTZ VEINS OF THE SOUTH URALS

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The vein quartz, large-grained and vitreous (semitransparent; and sometimes milky white), is translucent only on the margins and is always granular to some degree or other. In vitreous or glassy quartz are found fine very transparent portions. Vitreous and milky white quartz is turbid to a different degree due to the inclusions of gases and liquids (vide G. N. Vertushkov's "Vein Quartz from Veins of the Eastern Slope of the Urals" in Doklady, Vol 61 No 1 1946, pp53-56).

In certain veins the quartz is mainly granular, being converted into granular quartzite-like aggregates. One seldom observes in vitreous quartz small portions of laminated quartz in one or two directions (vide Vertushkov's "Laminated Quartz with Rock Quartz" in Zap. Min. Obshch, 75 No 4, 1946, pp 259-264). "Embedded" and exposed micro-fissures intersect one another; the first ones occurred earlier than the second ones. If all the fissures were removed, imagiaarily, from vein quartz, then transparent large-grained aggregate would be obtained. After its formation in the vein this quartz broke up more or less; fissures that formed then were closed up! In subsequent times already considerably metamorphicized primitive quartz was subjected to compressions which caused the partial transformation into grainy quartz and laminations. Subsequent processes of mechanical deformations of the veins are connected with the complete or partial crushing of the quartz, in consequence of which it received that peculiar structure which caused the local inhabitants to call it "rezunets," meaning "cut" (vide N. D. Vysotskiy's "The Gold Deposits of the Kochkarsk System" in Trudy Geol. Kom., Vol 13, 1900).

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According to the time of formation the original vein quartz, namely the last mineral in the veins, cemented together all earlier-formed minerals. Minerals that formed earlier than quartz are of the greatest interest. At present we find these veins: pyrite, rutile, hematite, corundum, andalusite, sillimanite, cyanite, biotite, muscovite, feldspar, and chlorite. Their quantity in the veins is comparatively small and inconstant; only chlorite and muscovite are in every vein. All minor vein minerals are concentrated for the most part near the boundaries between the veins and the wall rocks. Minerals rich in aluminum are encountered in great quantities in the veins located close to the contact with the boundaries.

Andalusite in considerable quantities is encountered in veins not far from the Kosarevsk settlement near a triangulation base-point. The crystals of this mineral reach up to 20 cm in length and 5 to 6 cm in diameter. They always show considerable variations: broken, displaced by muscovite or kaolinized, covered with black or brownish-yellow incrustations of iron or manganese hydroxide. Therefore one seldom succeeds in finding well preserved crystals. Moreover, andalusite is always included in quartz; this also complicates the gathering of its crystals. We had at our disposal not even one crystal for purposes of accurate measurements; we made all our determinations of forms by means of applied goniometers.

Among andalusite crystals the greatest development possesses faces of the following form: (110), (320), and (001), which explains the prismatic shape. The faces of the forms (100), (101), and (011) were observed on single samples.

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In the zone of [001] the faces (110) predominate; their overwhelming development explains the pseudotetragonal section of the crystals perpendicular to the axis of the zone. The faces (320) are comparatively poorly developed in contrast to the more or less smooth faces (110); they are covered by a deep vertical hatchure. In the fragment of one crystal was very clearly noted a face of the form (100). The prismatic faces truncate the faces of the basopinacoid (001); they are always greatly developed. Poorly developed faces of the forms (101) and (011) are seen only in rare samples.

The cleavage of andalusite relative to (110) is very clearly noted in all crystals; parallel to this direction the crystal is broken up by a fine system of cracks; the fracture is finely shell-like; the glance is glass-like; the color is white; in thin chips it is transparent; hardness is 7; brittle. The index of light refraction is around 1.63; it is strongly pleochroic from colorless to bright rose; expansion is negative; two-axial and negative.

All andalusite crystals in some degree or other are transformed into muscovite and kaolin. Rough scaly muscovite cover in a continuous coat the faces of the crystals and is always found in the form of fine scales inside of them. The transformation of andalusite into muscovite proceeds ~~according to~~ along the cleavage fractures. The greater part of the fine flakes of muscovite are regularly disposed perpendicularly to the cleavage planes of andalusite. As the flakes of muscovite become larger their orientation becomes more disrupted; there appear radial-flake aggregates of muscovite which are intruded deeply in the andalusite. One often finds pseudomorphs of muscovite relative to andalusite, in which (pseudomorphs) the original primitive mineral has been preserved in the form of fine flaky grains bounded by the cleavage planes of the andalusite crystals.

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Crystals of muscovite and their aggregates are considerably deformed and bent; in these fissures and cracks due to pressure and shock are clearly visible. Consequently andalusite is muscovitized as far as the granulation of the quartz. In quartz the surface of the impressions of andalusite crystals not only possesses negative forms of sculptured "decorations" of andalusite, but also contains andalusite leaflets deep in the quartz. To a certain degree this indicates that andalusite is muscovitized as far as the incrustation of the vein quartz.

Fine flaky or flat kaolin mainly replaces certain andalusite crystals. In rare cases pseudomorphs of kaolin relative to andalusite preserved the flat form of andalusite; not only the crystal form but also the entire fracture system characteristic of andalusites' deformed crystals are noted among these pseudomorphs. Now and then kaolin is colored yellow-brownish or black by iron and manganese hydroxides. Consequently the kaolinization of andalusite is ~~in point of point of~~ a later process in comparison with its very great granulation in quartz and probably kaolinization is connected with the zone of weathering.

Sillimanite is encountered in the same places as andalusite, but mainly in those veins where there is no andalusite; only in a few veins can these two minerals be encountered together. In this case, however, these minerals are found separately from each other. Therefore we did not succeed in establishing any direct determinations of the growth relations of andalusite and sillimanite. In ~~xix~~ veins sillimanite is concentrated mainly around casings and everywhere is fuzed together with the wall rocks; more rarely is its aggregate observed inside of vein quartz. A rather common phenomenon is sillimanite "fibers" -- inclusions of very fine needles and fibers of sillimanite in smoky rock crystal.

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Sillimanite aggregates are white, of felted structure (fibrolite), and is easily split into fine needles rather elastic and brittle. The total length of the needles in the aggregate reaches 5 to 7 cm. Under the microscope one can easily observe breaks in the individual crystals up to 1 cm in length and 0.03 to 0.05mm in width, but their depth is 4 to 5 times less than the width.

In the flame of a blowpipe sillimanite does not change; with $Co(NO_3)_2$ it acquires a blue color. Under a microscope it is colorless; its index of light refraction is about 1.65; extinction is direct; expansion is positive; biaxial and positive. The deformed needles possess cloudy extinction (dying out).

In granulated quartz one encounters everywhere sillimanite needles torn and somewhat displaced relative to the boundaries of separation of the quartz grains. In the deformation of vein quartz the sillimanite inclusions served as an unusual lubricant; within the quartz slipping occurred due to the inclusions.

Sillimanite inclusions in smoky rock crystals are separately fine needles reaching 5 cm in length and strongly bent and here and there entangled. In the needles are suspended chlorite "helminths" (vide D. P. Grigor'yev's "New Observations on Gravitational Shifts of Crystals in Alpine-Type Veins Found in the Juxta-Polar Urals" in "Doklady", Vol 44, No 5, 1944, pp 217-219). In places the suspensions in the needles often possess a flexture that is easily visible to the naked eye.

No variants in sillimanite were established.

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Cyanite in the outcropping of one of the veins was found in the form of parallel columnar aggregates disposed along the length of the axis almost normal to the walls of the fractures. From the wall of a fracture the crystals diverged somewhat to the side, in consequence of which their structure is radial-like. In certain cases this structure is strongly disrupted mechanically and the crystals are placed slantwise or further parallel with the walls of the vein. In the wall rocks of a vein are many fine cyanite crystals oriented in a confused manner relative to one another.

The shape of the crystals is plano-prismatic, all the faces are disrupted; the crystals bound the cleavage planes according to (100) and (010). The length of preserved crystals reaches 5 cm; the parallelepipedal fractures on the diameter are up to 0.5cm thick and wide. Many crystals are bent because of the displacement on a plane almost perpendicular to the c-axis; all cleavage planes disrupt light reflection. With respect to the planes of displacement, the crystals are easily distinguished, disrupting complete cleavage.

The color of cyanite is blue and light blue; the coloration is distributed unevenly and is mottled, but the intensively colored portions generally stretch through the main zone.

The glance on the cleavage planes is nacreous and its streak colorless; the hardness through the crystals is 4 and is 7 across the crystals. In the flame of a blowpipe it does not melt and is discolored; it turns blue with $Co(NO_3)_2$. Under a microscope it is transparent; expansion is positive; angle of extinction is 31°.

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Cyanite is found with a considerable quantity of muscovite filling the interstices between the cyanite crystals; flaky crystals of hematite and spiny red-colored crystals of rutile are also found.

Corundum is found in the form of fine crystals in the root part of coarse andalusite crystal. At the place of corundum inclusion, andalusite is strongly muscovitized. Flakes of muscovite are up to 0.5 cm in diameter, forming radial scaly aggregates, and grow deeply into the andalusite . Inside the andalusite crywtals, corundum inclusions were not observed.

The shape of corundum crystals is columnar; length along the main axis reaches 3 mm and diameter is 1 mm; the cross-section perpendicular to the main axis is hexagonal. The form of the boundary could not be determined; we failed to isolate a whole crystal. On the faces of the crystals and in the fracture are seen regular fissures which record polysynthetic twins. Along the cracks, corundum grains are easily picked out.

The color of corundum is blue; under a microscope it displays pleochroism from light blue to blue; at large magnifications, fine pointed black inclusions are visible.

In the quartz veins of the Svetlinsk deposit is found biotite in the firm of ensiform crystals up to 10-15 cm in length, for a width up to 1 cm and thickness 3-4 mm. It is always vermiculitized and very often is muscovitized. The elongated crystals of this mineral cut the quartz in all possible directions; they also intersect andalusite and the boundaries of separation between quartz and

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andalusite. At the places of intersection there are no special variations in direction and form of the biotite crystals. Consequently, biotite is an earlier mineral than andalusite. At the same time, sillimanite needles are found in biotite crystals; they penetrate the biotite in all possible directions. This permits us to state that sillimanite is an earlier mineral than biotite. Therefore we can conclude that sillimanite in veins are evolved earlier than andalusite.

The secondary minerals in veins are the same as the rock-forming minerals of the containing rocks, the difference only consisting in the form of separation and concentration. The present mineral composition of the rock was obtained as a result of metamorphic variation in sedimentary rocks. We have no basis for distinguishing the genesis of secondary minerals in veins from the general process of rock metamorphization. Veins with aluminum minerals in this case can be considered as veins possessing a tremendous "thrust shadow."

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